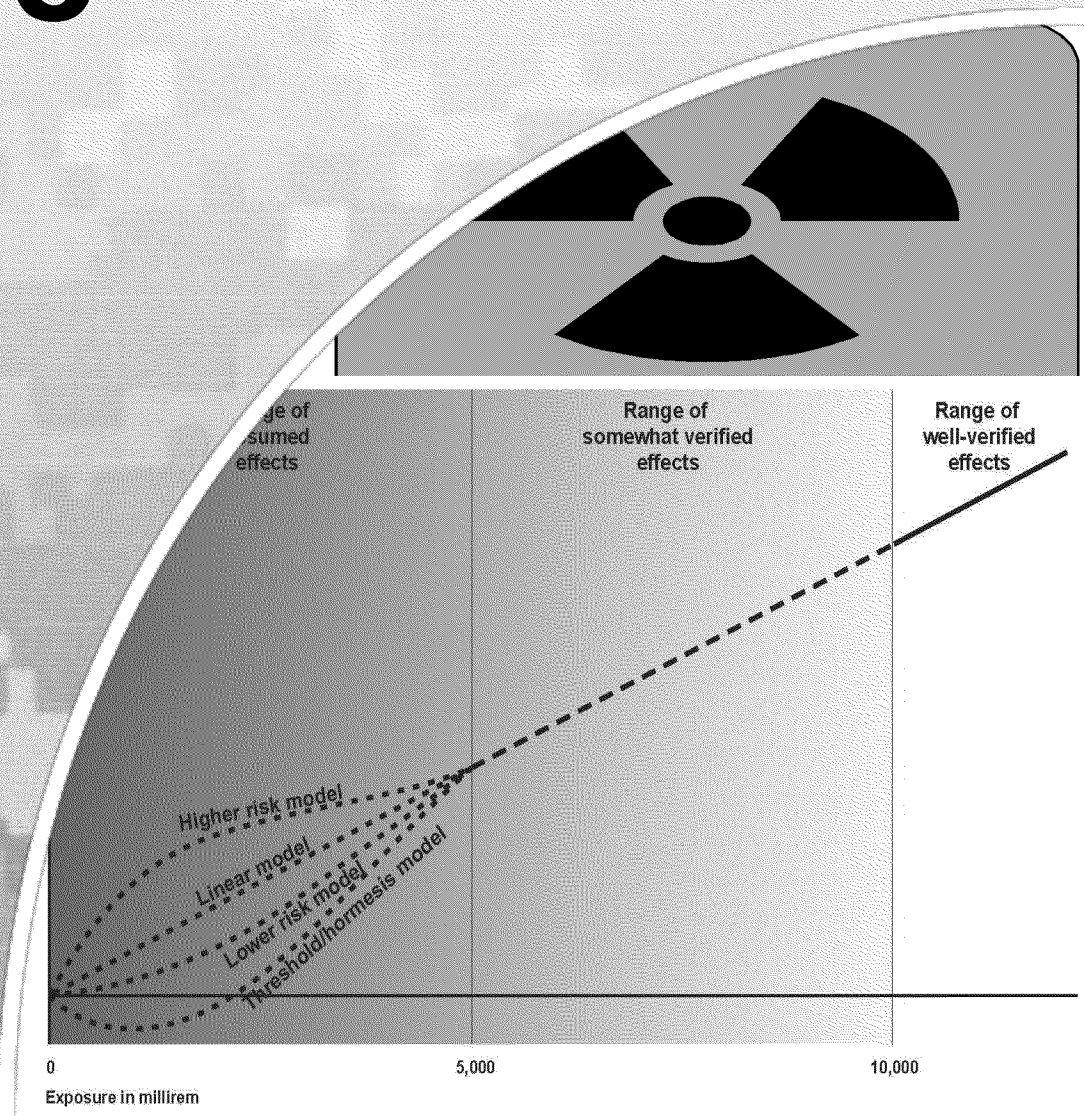
Radiation Risk in Perspective

USACE-NWK

8 September 2014

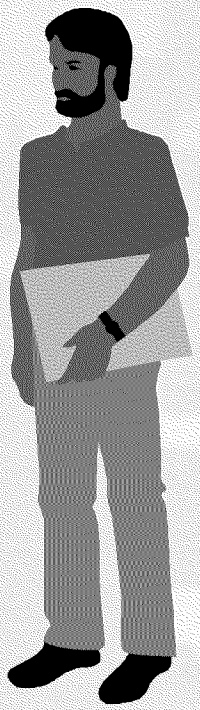


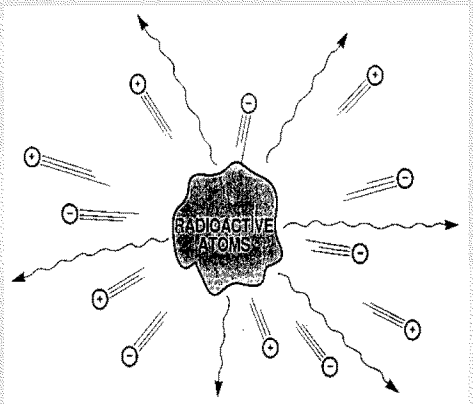
Discussion Outline

- What is a safe level of Radiation?
  - Radiation Basics
  - Dose vs. Risk Models
  - Regulatory Approach
- How is it determined if a site requires remediation?
  - Risk Assessments
  - How Remediation Goals are Determined
  - Preliminary Remediation Goals

Radiation Basics

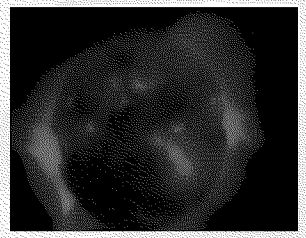
- **Radio"activity"** is the number of atoms decaying per time
  - For very low contaminated sites, units are picoCuries (pCi)
  - 1 pCi = 2.22 atoms decaying per minute
- Atoms decay by releasing energy and/or particles
  - When the particles hit us, energy is imparted
  - Results in exposure
- **Dose** is a measure of the impact of exposure
  - For very low contaminated sites units are millirems (mrem)
- **Risk** is a unit less value that expresses the chance of harmful effects resulting from exposure
  - At Superfund sites, risk is the chance that chemicals from a site will cause health and/or ecological problems.
- Dose relates to risk: generally, the higher the dose, the higher the risk

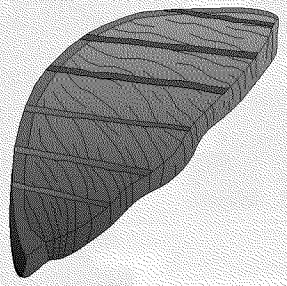


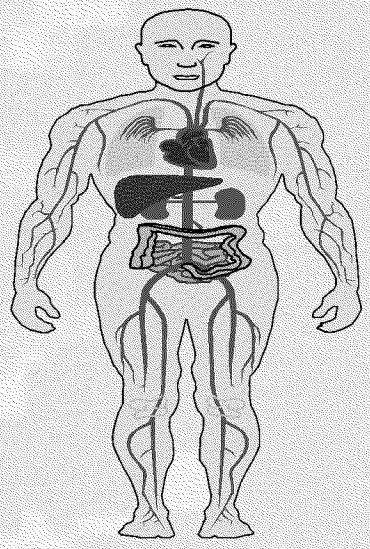


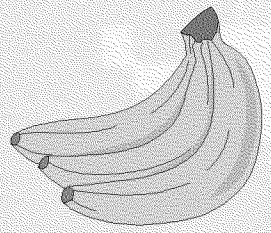
Radiation Sources

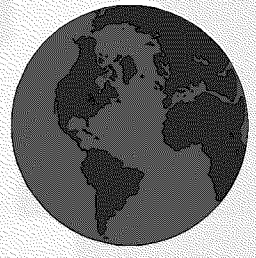
- Natural radiation is all around us
  - Cosmic photons and particles from the sun
  - Terrestrial materials in the earth's crust
  - Foods we eat
  - Internal in the body
  - In the air we breathe
  - In the water we drink
- Man made (non medical) radiation is a small fraction of our exposure





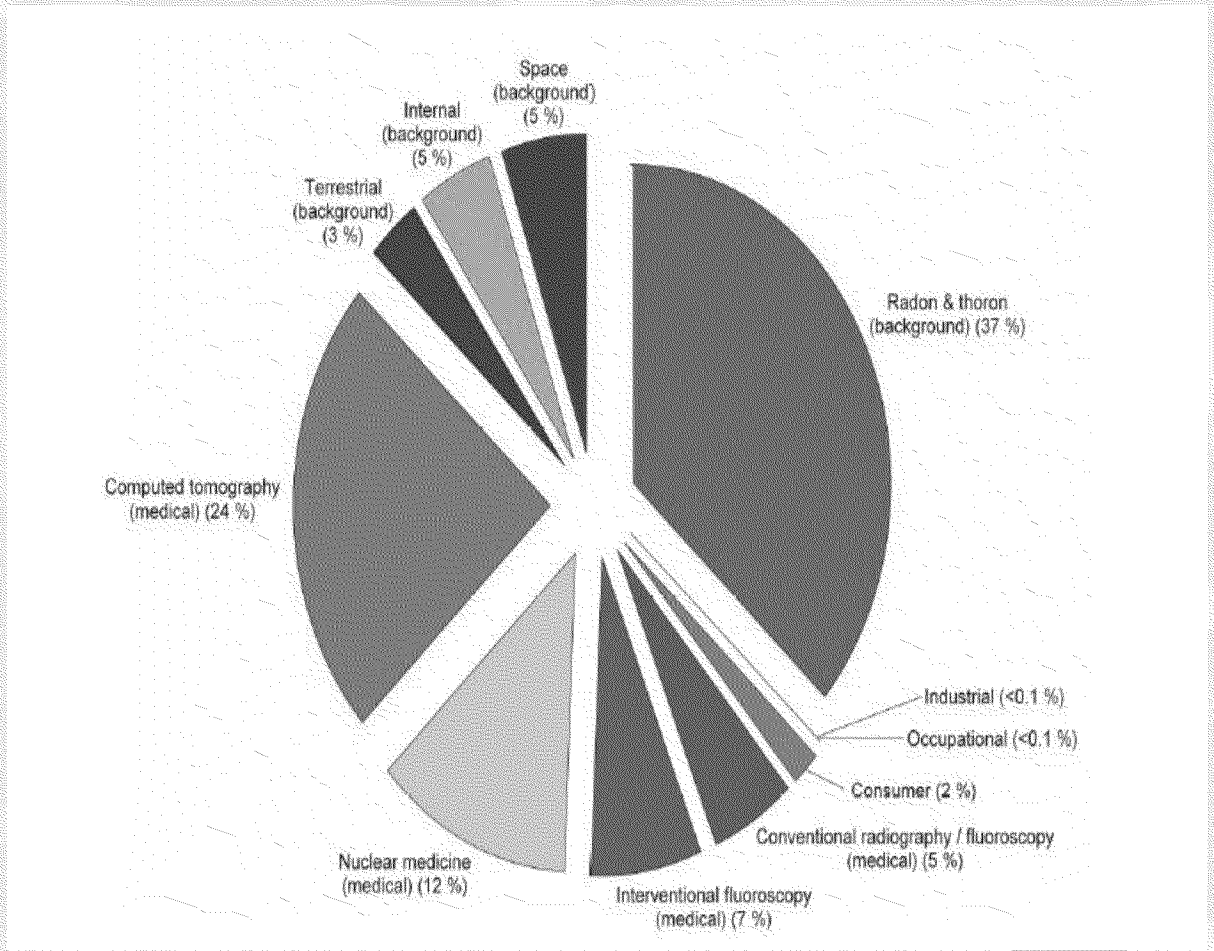






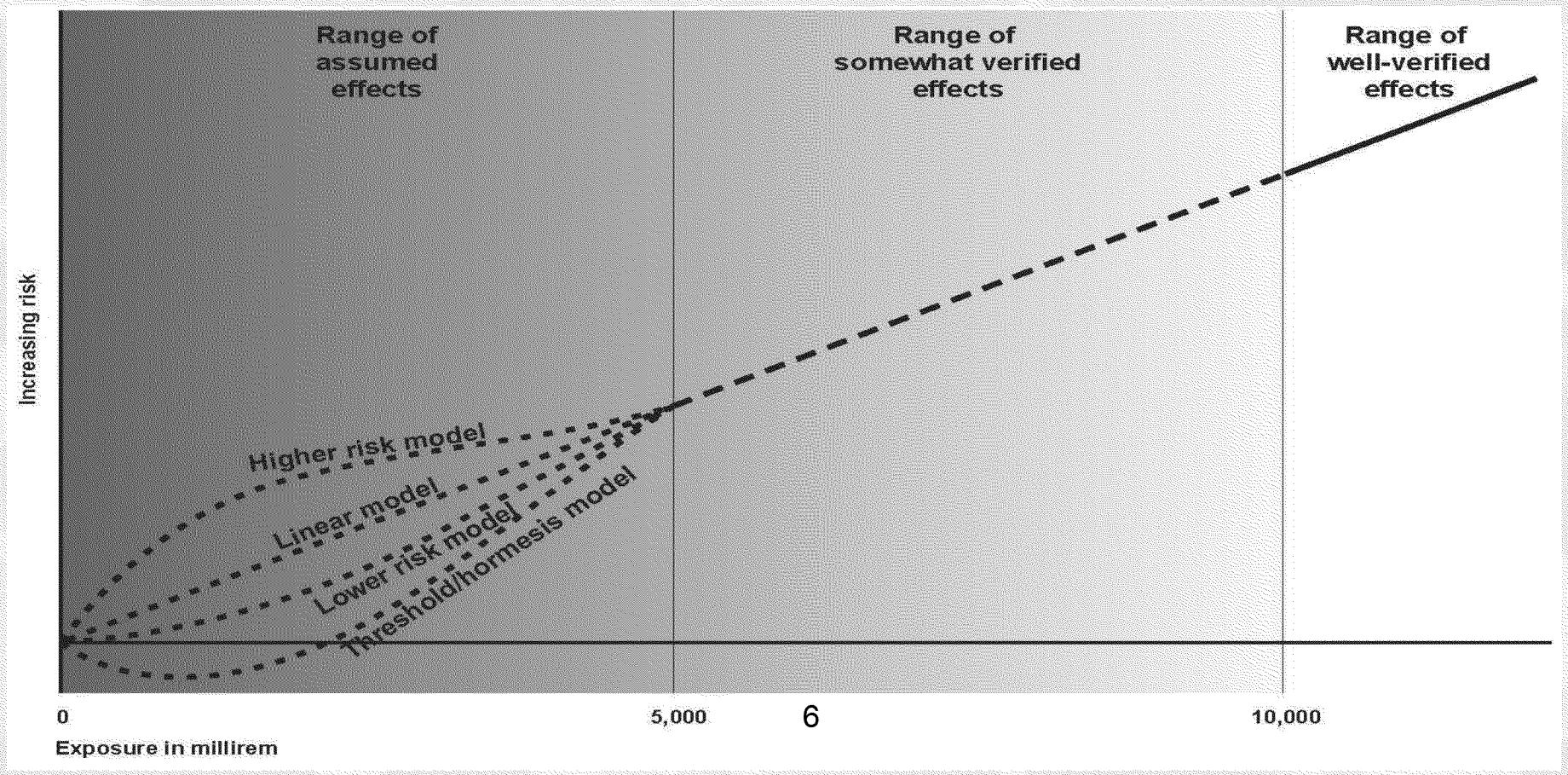
Radiation Exposure in the United States

- Everyone is exposed to radiation every day
- We are exposed to approximately 620 mrem per year
- Without medical dose, the average dose in St Louis area is approximately 340 mrem per yr



Dose to Risk Models

- We are exposed to radiation constantly, but what is safe?
- Several models estimate the dose to risk relationship
- Regulations are based on the linear model



Regulatory Approach

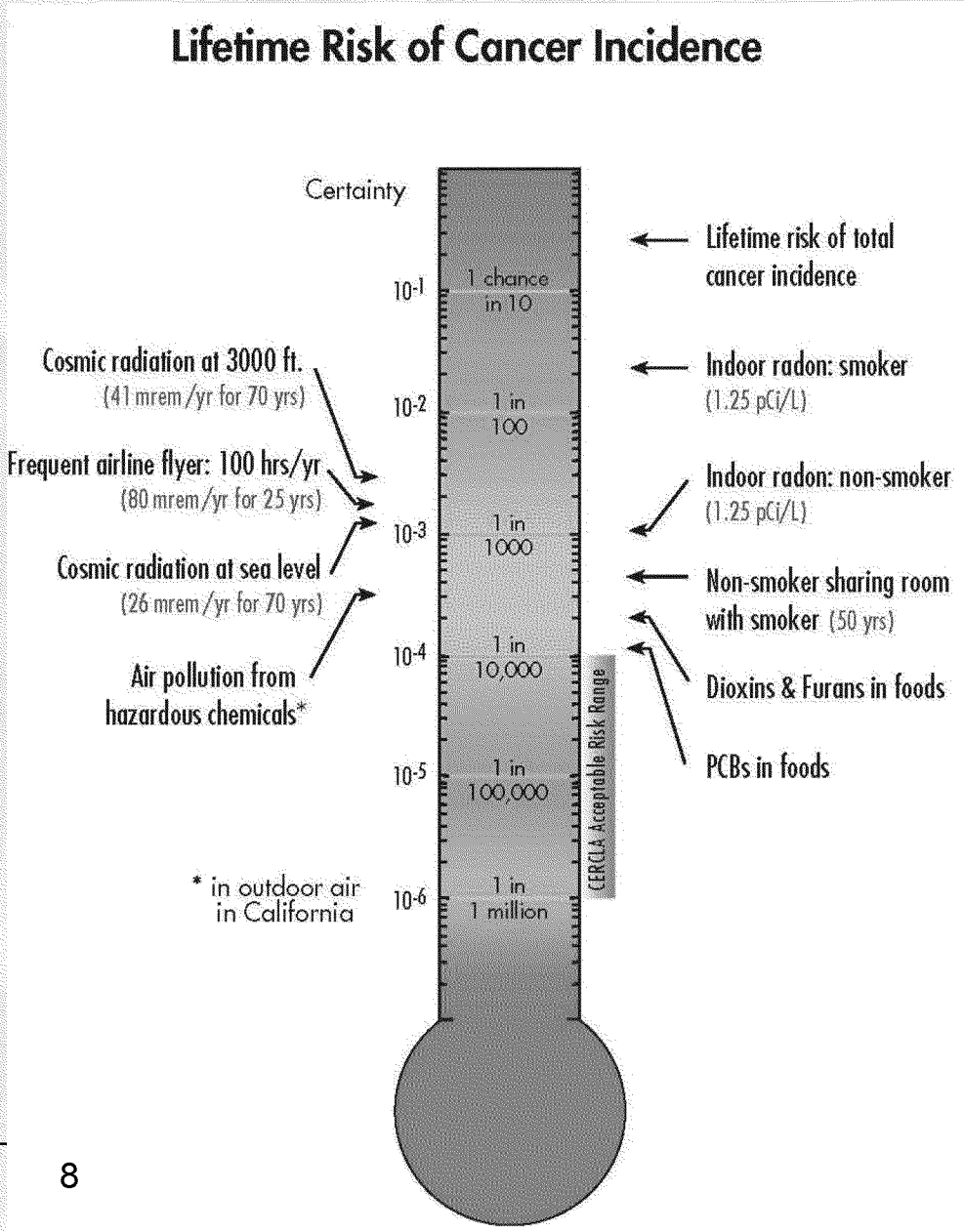
- The regulatory approach is based on the linear (no threshold) dose model
  - ► Conservative (likely overestimates risk)
  - ► Assumes a dose of radiation has the potential to cause an equivalent increase in risk

- EVERYTHING (driving, flying, smoking, etc.) carries some level of risk

- Regulations for hazardous waste sites refer to acceptable risk, not “safe” levels

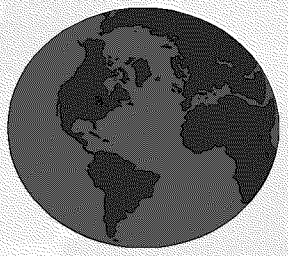
Regulatory Approach

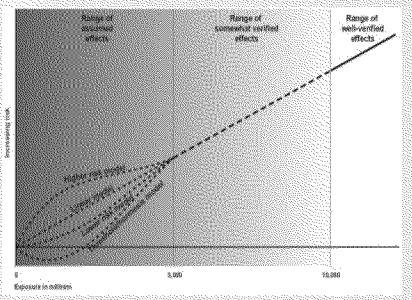
- 40 CFR 300.430(e) sets the (CERCLA) acceptable risk range for hazardous and radioactive waste sites
  - Carcinogen (Radionuclides) Acceptable Risk Range: 1 in 10,000 to 1 in 1,000,000 lifetime increase in cancer risk (note: risk of getting cancer not risk of death)
  - Chance of getting cancer is now roughly 1 in 2 for males and 1 in 3 for females
- Compare to risk of death:
  - Cancer 1 in 4(M) 5(F)
  - Driving (St. Louis) 1 in 10,000

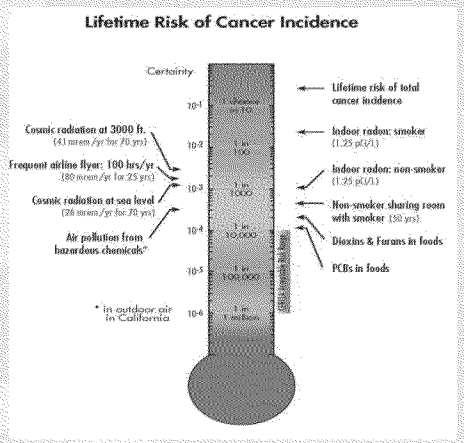


Recap of Key Points

- Everyone is exposed to radiation every day
- Regulations are conservatively based to ensure safety
- Regulatory approach is to state in terms of “acceptable risk”
- Acceptable risk range: 1 in 10,000 to 1 in 1,000,000 additional cancer risk (also referred to as $1x10^{-4}$ to $1x10^{-6}$)







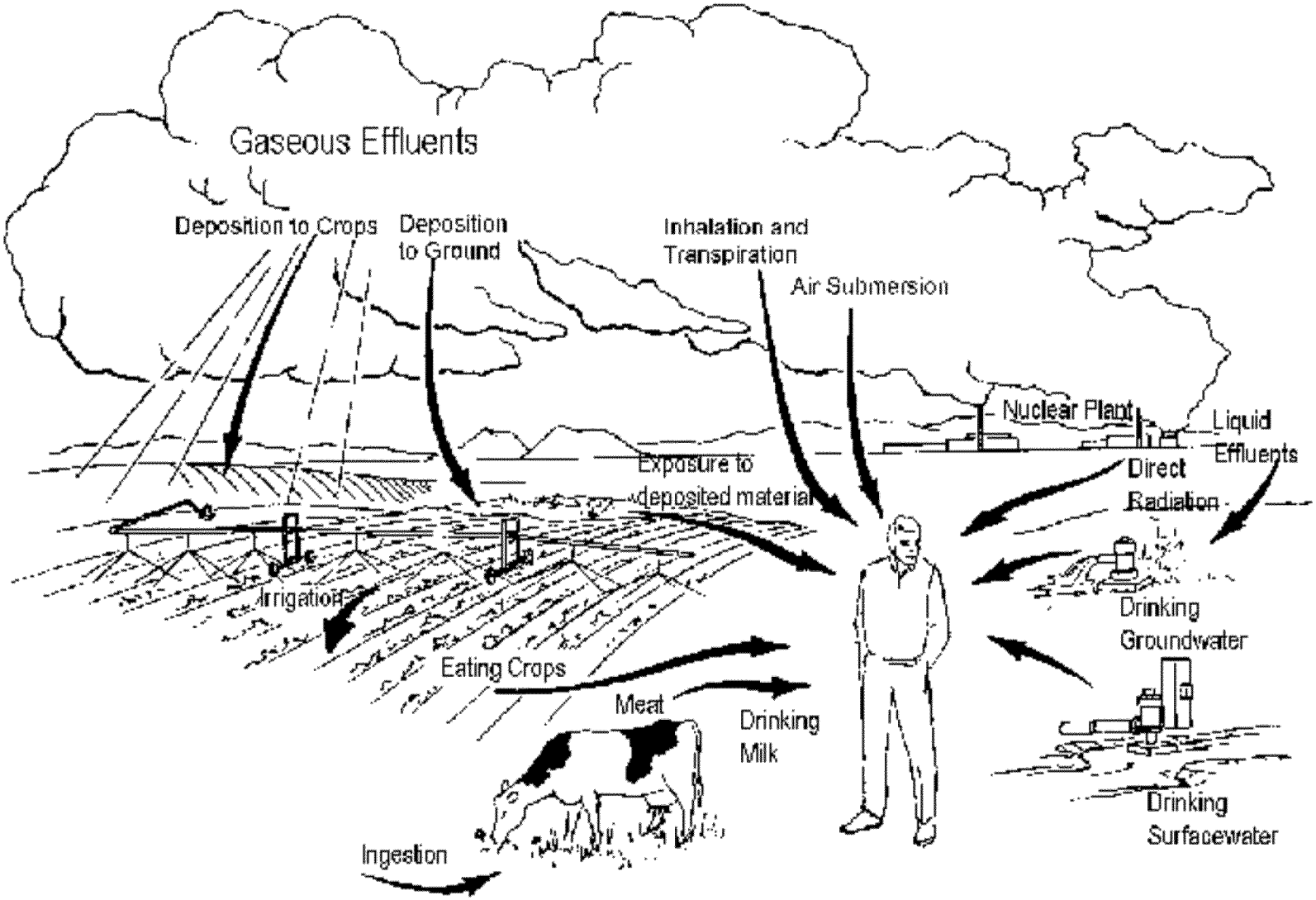
How is it Determined if a Site Requires Remediation?

- Hazardous waste regulations require a Health-Based Risk Assessment be performed and used to make decisions for addressing contamination at the site

- Risk Assessments:
  - Determine: Is there a risk? Who is at risk? How great is the risk? and What is causing the risk?
  - Evaluate all exposure scenarios:
    - Contaminants of concern (chemical and radiological)
    - Media of concern (soil, ground water, surface water, air, dusts, etc.)
    - Receptors (residents, workers, trespassers, ecological, etc.)
    - Exposure Pathways (inhalation, direct contact, ingestion, etc.)

- If risks exceed 1 in 10,000, action may be required
  - Engineering Controls
  - Land Use Controls
  - Remediation

Examples of Exposure Pathways

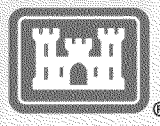


Determining Risk

- Only complete exposure pathways are considered
  - If groundwater is not used (in impacted area), no complete pathway
  - If surface soils not contaminated, off-site exposure due to dust inhalation is not a concern
- All land uses are considered (current and future)
- Evaluate carcinogens and non-carcinogens (utilize hazard quotients for non cancer causing effects)
- Conservative assumptions are built in to the variables used in risk assessment calculations
  - Conservative assumptions in risk assessments tend to overestimate risk

Example Risk Assessment Exposure Scenario

- Current Conditions
  - Contaminants (Uranium, Thorium, Radium)
  - Media impacted (surface soils)
  - Site security, fenced
  - Land use controls (no residential, no use of ground water)
  - Lab data and modeling results indicate no off-site inhalation receptors
- Potential Receptors
  - Current: Groundskeeper, security staff, trespasser
  - Future: Groundskeeper, recreational user, trespasser, commercial user, construction worker, adjacent building user, outdoor storage worker
- Potentially Complete Exposure Pathways
  - Inhalation of fugitive dust and radon
  - Incidental ingestion of soil
  - Dermal contact with soil
  - External radiation exposure from contaminated soil



BUILDING STRONG®

Example Risk Calculation

- For each receptor, chemical, and exposure pathway, risk calculations are performed
- Simplified example calculation for Cancer Risk due to inhalation:

$$C_{exposure\ pt} = C_{Air} \times (IR/BW) \times (ET \times EF \times ED) / AT$$

$$\text{Increased Cancer Risk} = IUR \times C_{exposure\ pt}$$

C=concentration (actual)
IR=inhalation rate (m3/hr)
ED=exposure duration (yrs)
EF=exposure frequency (d/yr)
AT=averaging time (d)
ET=exposure time (hr/d)
BW=body weight (kg)
IUR=Inhalation Unit Risk

- Complete all calculations, calculate the total risk for each receptor and pathway. Sum all calculated risks.
- If Total Cancer Risk > 1×10^{-4}, action may be required

West Lake

- Baseline Risk Assessment conducted in 2000 (OU1 Area 1, Area 2, Ford Property)
  - Carcinogens (including radionuclides & daughters)
  - Non Carcinogens
  - 1000 year study period, includes decay & in-growth
  - Per Risk Assessment Report
    - No exposure to off site receptors
    - Future risk for groundskeeper and outside storage worker exposures exceeded 1 in 10,000 risk
- Risk to be addressed through remedy

How are Remediation Goals Determined?

- Remediation Goals (RG) are sometimes referred to as clean up level, remedial action criteria, etc.
- RGs are primarily determined based on regulation or risk
  - Regulation may set acceptable RG level (may not be based on risk)
    - RGs set by regulations are considered protective
    - Examples: Maximum Contaminant Levels for drinking water and UMTRCA
  - Risk-based RGs are established to result in a target risk within the CERCLA risk range
- RGs are contaminant and media specific concentrations that demonstrate compliance with the remedial action objective of keeping risk within the CERCLA acceptable risk range

Impact of Background Levels on RGs

- When a constituent is not naturally occurring, there is no "background" concentration

- When a constituent is naturally occurring (ex: naturally occurring radioactive material), that naturally occurring amount is the "background" concentration

- Naturally occurring constituents are typically not remediated, therefore, the background concentrations are added to the RGs

Impact of Levels Background on RGs

- Although often presented as a single value, Background varies and is a range. It should not be thought of as a single value.

Nation	U238 (pCi/g)		Ra226 (pCi/g)		Th232 (pCi/g)	
	Mean	Typical Range	Mean	Typical Range	Mean	Typical Range
United States	0.9	0.1 - 3.8	1.1	0.2 - 4.3	0.9	0.1 - 3.5
Missouri	1.1	0.3 - 1.7	1.1	0.3 - 1.4	1.0	0.3 - 1.3
Ohio	1.4	0.8 – 2.2	1.5	0.8 – 2.5	1.0	0.7 – 1.5
Russia	0.5	0 - 1.8	0.7	0 - 2.1	0.8	0.1 - 2.1
Greece	0.7	0 - 6.5	0.7	0 - 6.5	0.6	0 - 5.1
West Lake	1.3	0.74-1.85	1.1	0.95-1.19	0.9	0.52-1.26

Different Sites Can Have Different RGs

- This is due to factors that impact how the RGs are determined:
  - Regulatory authority
  - Radiation standards / ARARs
  - Health assessment approaches
  - Land uses / exposure scenarios
  - Input parameters
  - Physical settings

West Lake

- West Lake Background (mean + 2σ):
  - Ra-226 1.06 + 0.24 pCi/g = 1.30 pCi/g (Missouri mean + 2σ: 1.7 pCi/g)
  - Th-232 0.9 + 0.66 pCi/g = 1.56 pCi/g (Missouri mean + 2σ: 1.6 pCi/g)
  - Ra-226 + Th-232 = 2.86 ≈ 2.9 pCi/g (Missouri Ra+Th = 3.3 pCi/g)

- Remediation Goal:
  - ARAR UMTRCA: 5 pCi/g + Background (Ra226, Th232)
  - UMTRCA goal is for residential use*
  - Background (95% UCL): 2.9 pCi/g
  - Derived Remediation Goal*: Ra-226 & Th-232: 7.9 pCi/g

* Use of UMTRCA residential remediation goal is conservative for West Lake, given land use restrictions that prevent residential use

What are Preliminary Remediation Goals (PRGs)?

- PRGs are used when first investigating a site to determine if additional investigation is needed (BMAC)
- Very conservative screening levels
- Follow the CERCLA acceptable risk range of excess cancer incidence rate of 1 in 1,000,000

Relative Risks for Comparison

- For comparison, some other lifetime risk factors
  - Death from heart disease ~ 1 in 6
  - Death from falls ~ 1 in 160
  - Death from storms ~ 1 in 30,000
  - Death from earthquake or landslide ~ 1 in 100,000
  - Death from lightning ~ 1 in 130,000
  - Death from food poisoning ~ 1 in 600,000
  - Death from accidental fireworks discharge ~ 1 in 650,000

* Source = National Center for Health Statistics 2008 Mortality Data

PRGs vs. RGs

PRGs

- Preliminary, not final
- Contaminant and media specific
- Risk based (generic scenarios)
- Usually do not consider
  - Site specifics
  - Technical Feasibility
  - Schedule
  - Resources
  - Costs
  - Regulations
  - Background
- Used as screening
- Very Conservative

RGs

- Final Remediation Goal
- Contaminant and media specific
- Must consider
  - Site Specifics
  - Technical Feasibility
  - Resources
  - Regulations (may not be risk based)
  - Risk
- Used to determine if site meets remedial action objectives

Summary

- Remediation Goals
  - Risk-based (site-specific calculations) or ARARs (regulations)
  - Remediation goals will be different from site to site
  - Background impacts
    - Background levels are ranges, not a single number
    - Vary from site to site
- Preliminary Remediation Goals
  - Screening only, used to determine if additional investigation is required
  - Intended to be very conservative

Summary

- What is a safe level of Radiation?
  - Radiation exposure occurs every day to every one
  - Regulations are conservatively based on the assumption that any exposure to radiation results in some risk
  - Regulatory approach is to state in terms of "acceptable risk"
  - Regulations define 1 in 10,000 increased chance of getting cancer as "acceptable risk"

- How is it determined if a site requires remediation?
  - Risk Assessment - who is exposed, what they are exposed to, how much they are exposed to, & how they are exposed
  - Risk Assessment results > 1 in 10,000 may require action

Questions?